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Biological Evaluation
R2-03-01

Biological Evaluation of Mountain Pine Beetle Activity on the Arapaho National Recreation Area (ANRA) and of Dwarf Mistletoe on ANRA Recreation Sites

December 2002

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Abstract

Lodgepole pine mortality due to mountain pine beetle (MPB) (*Dendroctonus ponderosae*) increased steadily in the Arapahoe National Recreation Area (ANRA) from 1997 to 2001 and remained high in 2002 according to aerial surveys. Potential MPB management areas designated by the Sulphur Ranger District were ground surveyed to determine the status of the beetle population. Selected campgrounds were surveyed for MPB attacked trees and systematically surveyed for dwarf mistletoe. Strip samples recorded the number of trees infested by MPB in 2001 and 2002 in four different areas covering over 125 acres. MPB infestation rates increased from 2001 to 2002 in all areas sampled. The 2002:2001 attack ratio varied from 1.4:1 to 3.1:1 and infested trees/acre in 2002 varied from 1.5 to 20.9, indicating that MPB populations are above endemic levels in all areas sampled. Analyzing areas based on management objective and MPB abundance will help select the best management tactics for a given area. No new mountain pine beetle infestations were found in Arapahoe Bay and Willow Creek campgrounds which had received preventive insecticide applications to protect high value trees.

Dwarf mistletoe information for ANRA campgrounds was collected through systematic ground surveys and analysis of existing stand exam data. Willow Creek, Green Ridge and Sunset Point campgrounds had light dwarf mistletoe infection with stand dwarf mistletoe ratings (DMR) from 0.0-0.5. Moraine, Big Rock and Roaring Fork Camping Loops at Arapahoe Bay had moderate infection levels with stand DMR from 0.5-3.0. Heavily infected stands with DMR over 3.0 were found in Stillwater Bay and Cutthroat Bay Campgrounds. Management recommendations for stands infested with dwarf mistletoe are discussed.

Introduction

The mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) is a native insect that plays a major ecological role in maturing lodgepole pine forests. MPB epidemics can cause dramatic tree mortality over extensive areas and the insect has been described as the most the most important biotic agent of change in western pine forests (Amman et. al. 1989). MPB kills trees by feeding on the phloem tissue and by introducing the blue stain fungus, *Ceratocystis montia* (Rumb) Hunt, which blocks the water conducting xylem tissue within the tree. MPB epidemics reduce the average stand diameter and age, and influence such things as canopy closure, stand structure, species composition, forage production, wildlife habitat, fuel loading, water yield and aesthetics. Downfall and woody debris following infestations can also hamper access and use of land by livestock, big game and humans (McGregor and Cole 1985).

Lodgepole pine stands that are susceptible to MPB typically have the following characteristics: average diameter at breast height (dbh) > 8 inches; average age > 80 years; and a suitable climate for beetle development determined by elevation and latitude (Amman et. al. 1977). Suitable climate for beetle development based on the latitude of the Arapahoe National Recreation Area (ANRA) is estimated to be below 9,450 ft. Outbreaks tend to occur at intervals of fifteen to twenty years in older lodgepole pine forests in the Rocky Mountains and may last for six to ten years (Cole and Amman 1980). Between outbreaks, low level (endemic) populations persist by selecting weakened or damaged trees, but no such selection is evident during high level (epidemic) populations (Furniss and Carolin 1977). Once an epidemic is underway, most large trees in the outbreak area may be attacked (Cole and Amman 1980). Smaller diameter and younger trees in and near outbreaks may be attacked and killed, but small trees alone are not capable of sustaining an outbreak (McGregor and Cole 1985). Stands having a large proportion of large diameter trees with thick phloem are most likely to be infested and will suffer proportionately greater losses (Amman et. al. 1977). Stress factors, such as current drought conditions, may contribute to stand susceptibility, but the exact triggering mechanism for the initiation of MPB outbreaks is not known. MPB epidemics do not require a landscape disturbance, such as fire or windthrow to be initiated or to spread. When factors favorable to MPB population increases coincide with host susceptibility, beetle outbreaks can result.

Management strategies for reducing MPB populations may exacerbate the incidence and severity of dwarf mistletoe if caution is not taken while designing silvicultural treatments. Lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. Ex Engelm.), a parasitic plant, is the most prevalent disease in the campgrounds of the ANRA. Lodgepole pine dwarf mistletoe causes severe damage and growth loss in lodgepole pine (Hawksworth and Johnson 1989). Dwarf mistletoes spread by forcibly expelling sticky seeds at speeds up to 60 miles per hour for an average maximum distance of approximately 33 feet. The seeds adhere to host needles and slide down the needle and infect thin bark tissue when moistened by rain. After the

initial infection, the parasite develops roots called "sinkers" that become embedded in the host xylem. This process takes several years but ultimately results in the production of mistletoe shoots on the host's stem and branches that in turn produce flowers and seeds. Mistletoe plants get their food and nutrients from the living host. As stand density increases and available light declines, mistletoe infections can become latent. Latent infections may reactivate as stands are thinned and more light is introduced into the stand. Spread of dwarf mistletoe is slowest in dense even-aged stands and fastest in uneven-aged stands of lodgepole pine.

Current Situation

The ANRA is managed for recreation and receives over 1.5 million people visiting each year. The area is adjacent to Rocky Mountain National Park and its west entrance. It includes scenic corridors, five major reservoirs and twenty-two developed recreational sites. A key component for managing the ANRA is the retention of mature forest vegetation for scenic and aesthetic values. Management direction includes both prevention and suppression of insect and disease infestations in developed recreation sites and main scenic corridors (USDA Forest Service 1997).

Lodgepole pine mortality from MPB began to increase on the ANRA in 1997 and has been at notably higher levels since 2000 (Johnson 2002). Federal, state and private lands have been affected by the increase in lodgepole pine mortality from MPB.

The current outbreak has generated concern among residents in the wildland/urban interface areas around Lake Granby, Shadow Mountain Lake and Grand Lake. Residents are faced with the loss of mature tree cover, increased hazard and fire danger from the standing dead trees. Some of these landowners have treated infested stands through logging in an effort to suppress beetle populations and reduce stand susceptibility to beetle attack and have requested that Forest Service treat adjacent NFS lands to suppress MPB and to reduce fuels across a broad landscape.

The Sulphur Ranger District has identified potential areas for MPB management (3,330 acres) and areas for fuels management (3,421 acres) within the ANRA (Figure 1). Some of these areas overlap, so actions in these areas will accomplish both management objectives. Proposed action is to improve overall forest health and reduce fuels through forest management actions. Management efforts will be located in developed recreation sites, main scenic corridors, areas adjacent to private property to complement treatment efforts on private lands, and other high value areas where forest conditions are at risk.

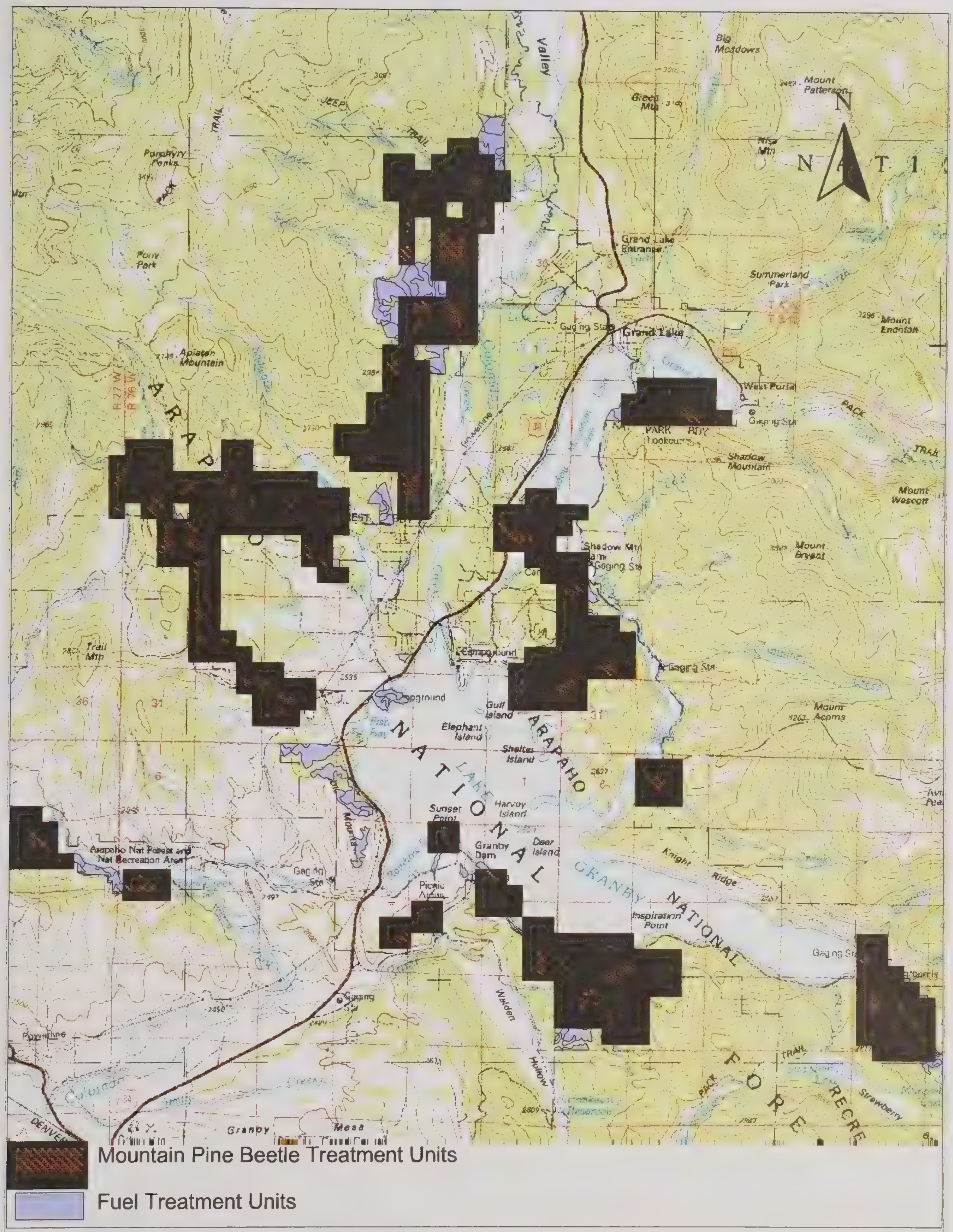

Figure 1. Proposed Mountain Pine Beetle and Fuel Treatments for the Arapahoe National Recreation Area.

Figure 1. Proposed Mountain Pine Beetle and Fuel Treatments for the Arapahoe National Recreation Area.

Purpose

This evaluation documents the current status of MPB on the ANRA and adjacent areas and provides recommendations for managing bark beetle impacts on the ANRA. It also documents dwarf mistletoe conditions within the campgrounds of the ANRA and provides management alternatives that could decrease susceptibility to MPB while preventing increases in the incidence and severity of dwarf mistletoe in current and future stands.

Methods

Current MPB conditions for the ANRA were estimated by aerial survey, strip samples in selected management areas and walk-through surveys in selected campgrounds.

Dwarf mistletoe information was collected in all ANRA campgrounds by walk-through surveys and supplemented by systematic variable radius plot samples and stand exam data.

Aerial Survey

Aerial surveys were conducted from a fixed wing single engine aircraft about 1,500 feet above the ground at approximately 100 miles per hour in late summer after infested trees began to fade. Erik Johnson (Aerial Survey Program Manager, FHM) performed the aerial surveys. Areas of lodgepole pine killed by mountain pine beetle were sketch mapped onto 1:100,000 scale USGS 30X60 minute topographic maps.

MPB Strip Samples

Strip samples recorded the previous year's MPB-killed trees and current year's MPB infested trees along transects one chain (66 ft.) wide and varying length. Variable radius 10 factor prism plots were taken approximately every one quarter mile or at least one per transect to determine average live basal area of the strip sample. Diameter at breast height (dbh) was taken for all “in” trees at each plot and averaged for each plot, strip sample, and area.

Four separate areas were surveyed within or near the Draft EIS proposed MPB management areas. Transect survey lines totaling 15.6 miles covered approximately 125 acres.

Descriptions of areas surveyed:

1. Green Ridge Wildland/Urban Interface Area included six transects through federal forest lands adjacent to the Shadow Mountain Shores subdivision totaling 4.7 miles and covering 37.6 acres (Figure 2).

2. Green Ridge Roadless Area included three transects across National Forest lands south of the interface area on the Green Ridge peninsula covering 3.7 miles and 29.6 acres (Figure 2).

3. Arapahoe Bay Road Area included 4 transects off Arapahoe Bay Road on the south side of Lake Granby and south of the Doe Creek trailhead covering 3.3 miles and 26.4 acres (Figure 3).

4. Stillwater Creek and Soda Creek Area included 10 transects covering 4.0 miles and 32.0 acres northwest of Lake Granby in and near the Stillwater Creek and Soda Creek watersheds (Figure 4).

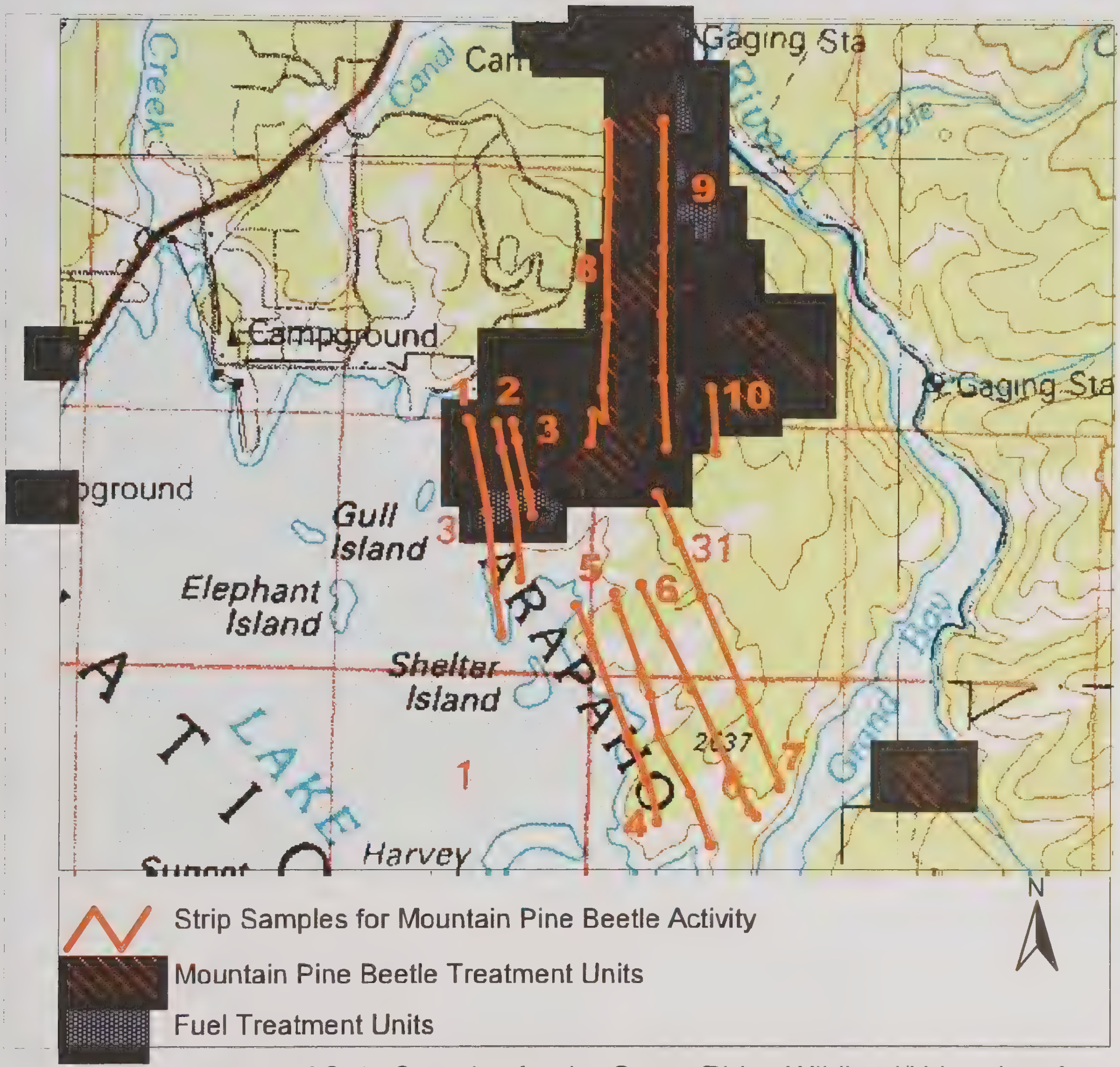

Figure 2. Location of Strip Samples for the Green Ridge Wildland/Urban Interface and Roadless Areas on the Arapahoe National Recreation Area.

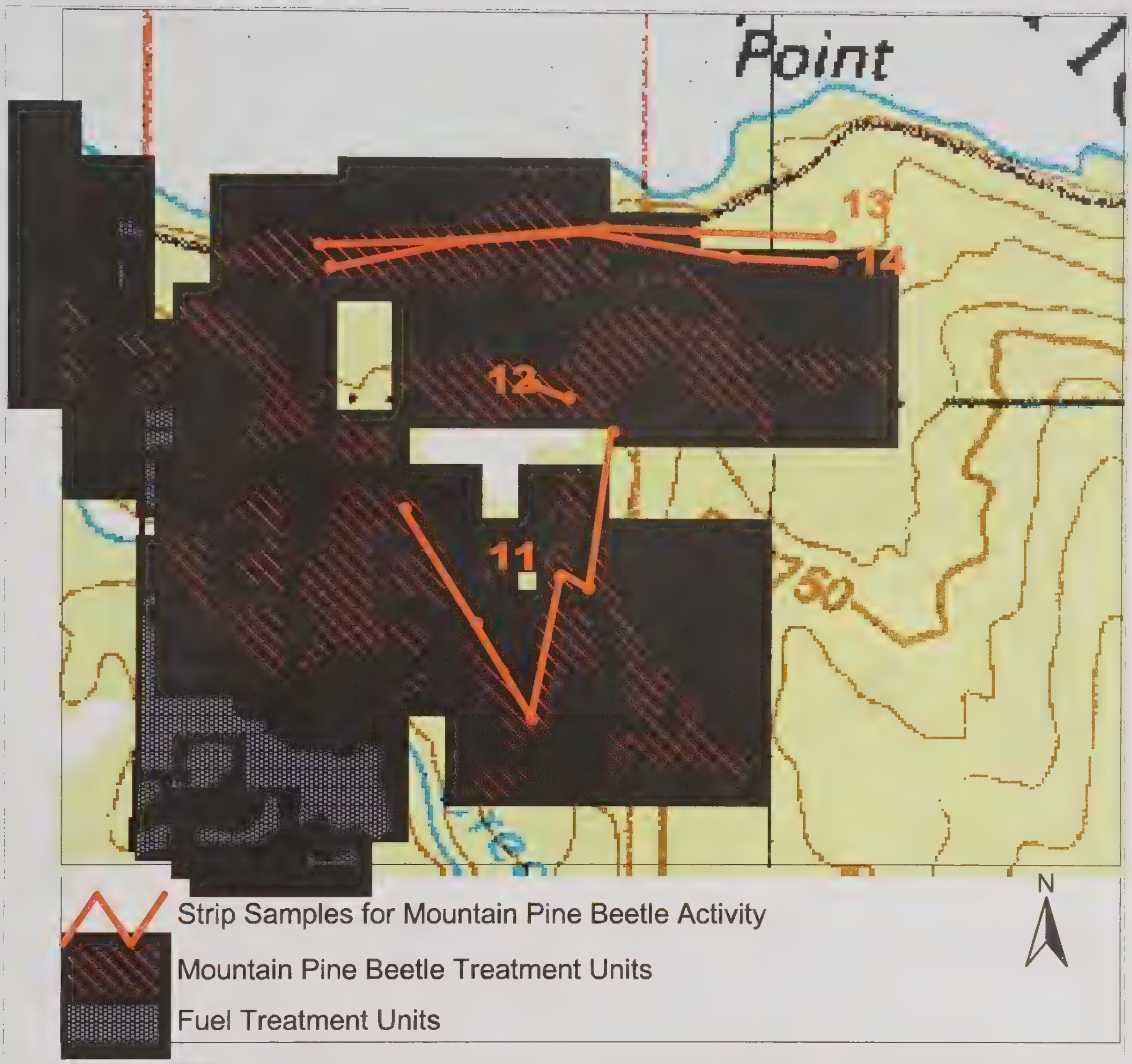

Figure 3. Location of Strip Samples the Arapahoe Road Areas on the Arapahoe National Recreation Area.

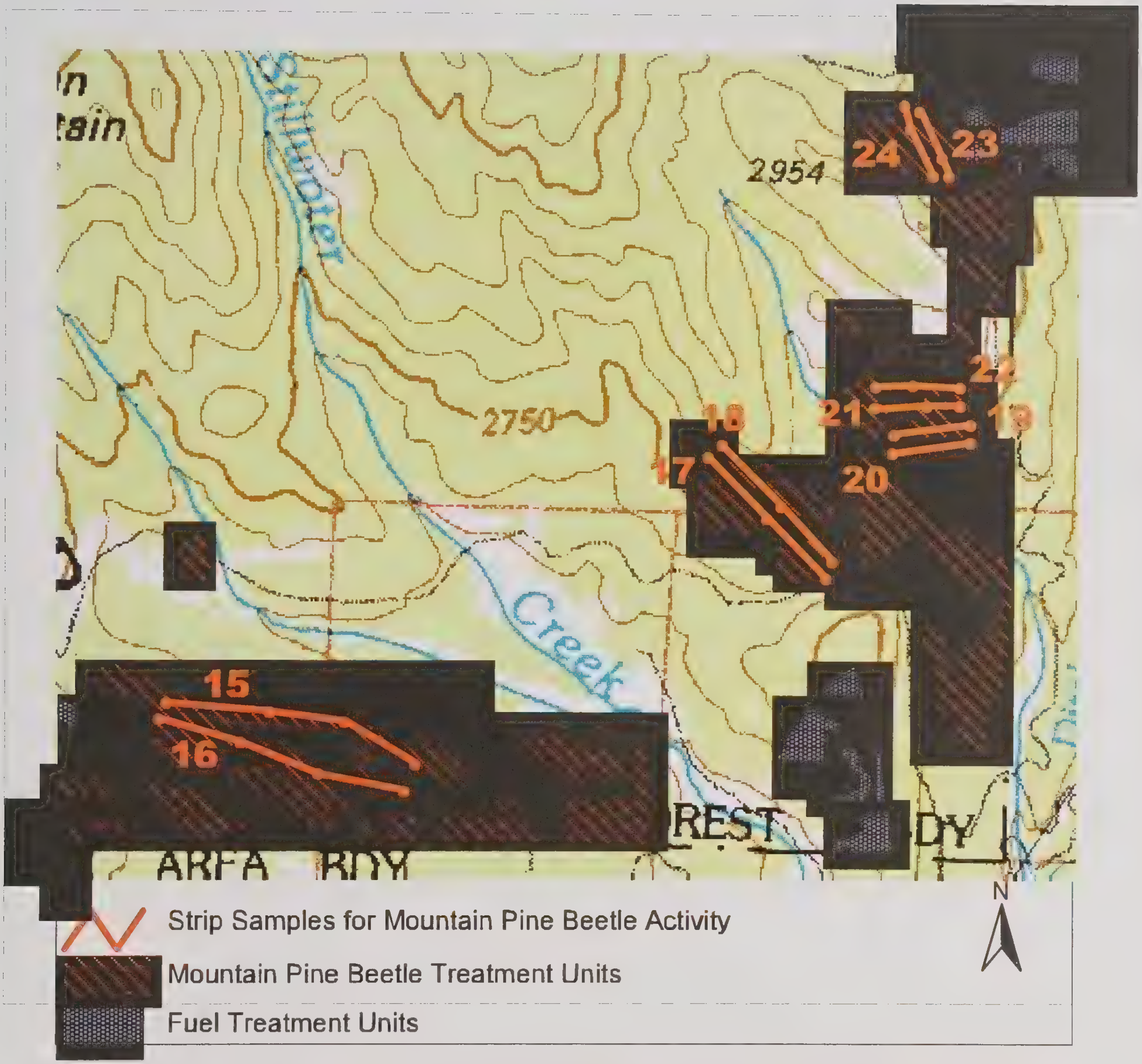

Figure 4. Location of Strip Samples in and near the Stillwater Creek and Soda Creek drainages on Arapahoe National Recreation Area.

Campground Survey

A walk-through MPB survey of campground trees was conducted at Roaring Fork, Moraine and Big Rock Loops of Arapahoe Bay Campground at the east end of Lake Granby in mid October and at the Willow Creek Campground on the Willow Creek Reservoir in late July.

Stand exam data (2001 surveys) provided by the Sulphur Ranger District were used to identify baseline conditions in campgrounds with regard to dwarf mistletoe levels and stand characteristics. Stand exam information was verified in the field by walking through campgrounds noting mistletoe incidence and severity. In campgrounds where dwarf mistletoe was obviously present, a series of variable

radius plots were established and information on species, diameter at breast height (DBH), dwarf mistletoe rating (DMR) (Hawksworth 1977), and the presence of other diseases were recorded. Stillwater, Arapahoe Bay (Moraine, Big Rock, and Roaring Fork Loops), Cutthroat Bay, and Green Ridge campgrounds were surveyed. Since Sunset Point and Willow Bay Campgrounds had little or no mistletoe, plots were not installed but stand exam data was summarized.

Results and Discussion

MPB is increasing throughout susceptible stands on the ANRA. MPB has already reached epidemic levels in susceptible stands surveyed on the Green Ridge roadless area and on some of the wildland/urban interface areas around Lake Granby. Dramatic landscape changes from MPB-caused tree mortality can be seen on Knight Ridge (Figure 5). This area demonstrates the potential course of the epidemic in susceptible stands where no management actions are taken. Susceptible lodgepole pine stands adjacent to Knight Ridge and private lands north of the Lake Granby may follow a similar course of high tree mortality if no management actions are taken immediately. Some of these areas already have high populations of MPB and tree mortality. The current MPB outbreak on the ANRA is showing no signs of collapsing. Aerial survey showed continued high levels of MPB associated tree mortality and strip samples indicated that the infestation increased in all surveyed areas in 2002.

Figure 5. Lodgepole pine mortality due to MPB on Knight Ridge, October, 2002

Aerial Survey

Aerial surveys document a steady and rapid increase in tree mortality attributed to MPB from 1997 – 2001 and continued high levels in 2002 across all land ownerships in the four townships around Lake Granby (Figure 6). The number of MPB-killed lodgepole pine more than doubled in Grand County from 65,000 in 2000 to 150,000 in 2001 (Johnson 2002). Areas that continue to experience the most MPB in the county are around Lake Granby, along the William's Fork River and throughout the Troublesome Creek watershed (Johnson 2002).

Aerial survey data reveals trees attacked and killed the previous year but does not accurately estimate the currently infested green trees. Aerial surveys provide trends and approximate location information that facilitates ground survey, but does not convey exact numbers or acres of infested trees. The MPB outbreak is continuing and additional lodgepole pine mortality is expected in the future.

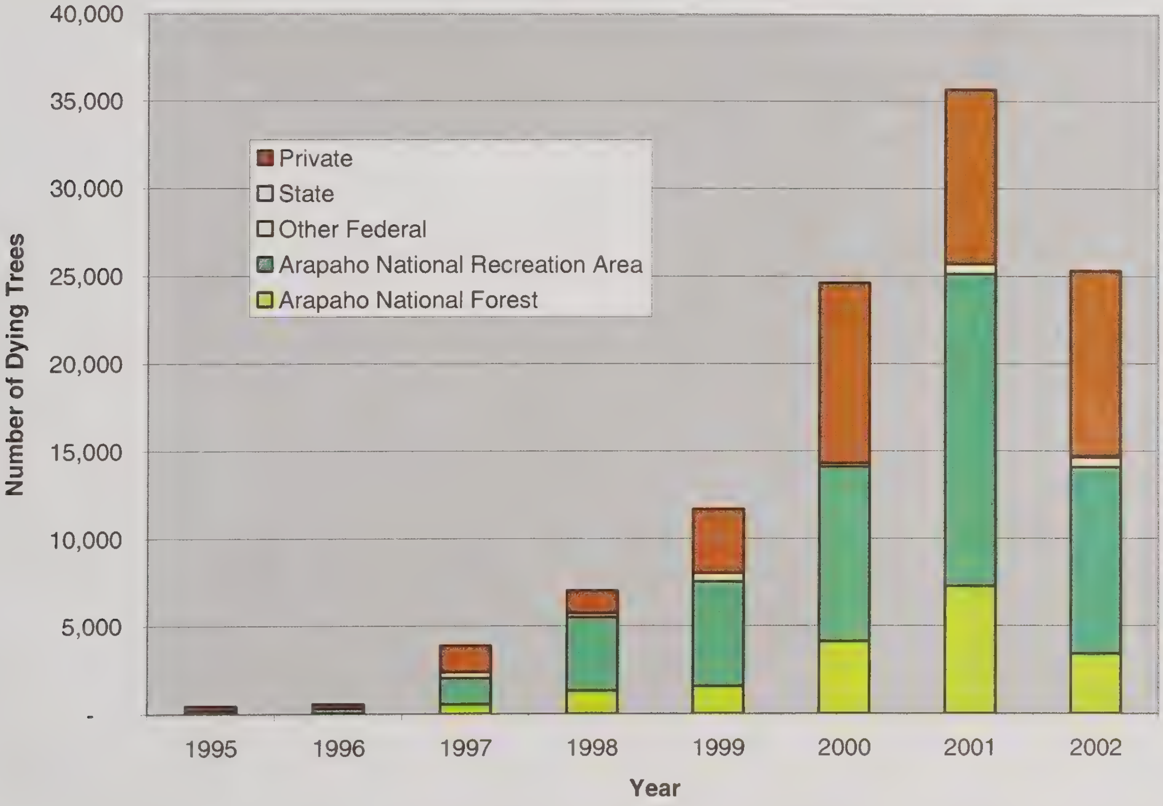

Figure 6. Comparison of aerially detected lodgepole pine mortality attributed to MPB from 1995 to 2002 by land ownership in the Lake Granby area.

Strip Samples

Strip sample data estimates currently infested trees per acre. A comparison of the number of trees infested from year to year expressed as a ratio indicates whether a population is increasing, decreasing, or static, and how quickly it may be doing so.

Cole and Amman (1980) reported that MPB infestations measured in Forest Service Regions 2 and 4 indicated the following pattern of an outbreak that is helpful in interpreting our strip sample data. Infested trees numbered from 0.5 to 5.0 trees per acre in the early years of an outbreak, and increased to 26 to 31 trees per acre during the peak of the outbreak, and declined to 2 to 3.5 trees per acre following the peak. After most of the large diameter trees have been killed the outbreak subsides (Cole and Amman, 1980).

Green Ridge Wildland/Urban Interface - There was greater than a three-fold increase in beetle attacks from 6.5 trees/acre in 2001 to 20.1 trees/acre in 2002 (Table 1). The average basal area/acre for this area was 112 and the average DBH was 8.2 (Table 1). The 2002:2001 attack ratio was 3.1:1 (Table 2). On-going MPB activity will likely continue to reduce average stand diameter and density in this area. Projected changes in diameter and density are well illustrated in strip sample number 8 where currently infested trees will reduce average stand density by 32 sq. ft. per acre and average stand diameter by 0.7 inches in just one year (Table 3). Stand conditions indicate there is still a significant amount of susceptible trees in this area. New MPB attacks were more heavily concentrated on transects 8 and 9, just east of Shadow Mountain Shores subdivision (Table 3).

Table 1. Summary of strip samples for the survey areas for the Arapahoe National Recreation Area completed in September 2002.

Areas	Number of Plots	Acres Surveyed	Mean DBH (inches)	Mean BA/Acre (sq. ft.)	2001 MPB Trees/Acre	2002 MPB Trees/Acre
Green Ridge Urban/Interface	18	37.5	8.2	112	6.5	20.1
Green Ridge Roadless	14	29.4	9.6	104	7.4	20.9
Arapahoe Bay Road	13	26.4	9.5	152	3.6	5.1
Stillwater and Soda Creeks	16	32.0	9.3	120	1.2	1.5
All Areas	61	125.3	9.1	121	3.9	12.4

Table 2. 2002:2001 MPB attack ratios by area surveyed

Area Surveyed	2002:2001 Attack Ratio
Green Ridge Wildland/Urban Interface	3.1:1
Green Ridge Roadless Area	2.8:1
Arapahoe Bay Road	1.4:1
Stillwater Creek and Soda Creek Area	1.25:1

Green Ridge Roadless Area - Greater numbers of trees on Green Ridge will fade next year as surveys indicate a three-fold increase in green infested trees from 7.4 in 2001 to 20.9 in 2002 (Table 1). This particular sampled area is outside of the proposed MPB management units, but adjacent to the wildland/urban interface area and in a prominent viewshed above Lake Granby. Average basal area/acre in the

surveyed area was 104 and average tree dbh was 9.6 (Table 1). Stand structure was more diverse in the northern end of these strip samples varying from small diameter, dense stands to larger diameter stands of varying densities. The greatest number of beetle attacks and the highest risk stands based on lodgepole diameter and density were in the southern end of this area. Highly susceptible stands still exist throughout the roadless portion of Green Ridge and the MPB population is likely to continue to increase in these stands. The extent of additional tree mortality in the epidemic is unpredictable, but it is likely to be very high in stands with susceptible trees.

Table 3. Strip sample mean basal area (BA) per acre, mean lodgepole pine diameter at breast height (dbh) and number of MPB attacks per acre by year and survey area on the Arapahoe National Recreation Area.

Transect Areas	Strip Sample Number	Number of Plots	Mean BA/acre (sq.ft)	Mean dbh (inches)	2001 Attacked trees/acre	2002 Attacked trees/acre
Green Ridge Wildland/ Urban Interface	1	3	97	9.7	5.5	2.6
	2	3	83	5.8	0.6	2.4
	3	1	50	9.8	4.4	2.0
	8	5	118(86)*	8.3(7.6)*	10.7	30.0
	9	5	128(122)*	8.7(8.5)*	5.8	35.7
	10	1	190	7.1	10.0	22.3
Green Ridge Roadless	4	2	110	8.8	3.9	9.5
	5	4	117	9.0	6.2	19.4
	6	3	87(63)*	10.0(9.7)*	5.9	19.4
	7	5	102(76)*	10.2(9.5)*	8.8	22.0
Arapahoe Bay Road	11	4	128	10.4	4.1	7.8
	12	1	210	7.0	0.0	3.4
	13	4	152	8.6	2.7	4.7
	14	4	162	10.0	4.2	2.1
Stillwater and Soda Creek Drainages	15	3	87	8.4	0.0	0.0
	16	3	60	9.6	1.0	1.1
	17	2	165	10.2	2.5	0.7
	18	2	100(93)*	8.7(8.3)*	2.6	4.2
	19	1	230	10.0	2.7	4.3
	20	1	130	10.9	1.5	1.5
	21	1	160	9.4	1.0	3.9
	22	1	170	7.4	0.0	0.0
	23	1	110	9.1	0.0	0.0
	24	1	150	9.9	1.1	0.6

*Numbers in parentheses are projected BA and DBH in 2003 for transects based on the number of infested trees in the prism plots.

Arapahoe Basin Road – Strip samples along Arapaho Bay Road indicated MPB populations well above low or endemic levels with 5.1 newly infested trees per acre (Table 1). The MPB caused tree mortality is increasing at a modest rate of 1.4:1 between 2002 and 2001 (Table 2). Pockets of tree mortality will continue to increase

and new pockets will become noticeable next year. This area has a predominantly north facing aspect and supports the highest density of large diameter trees of all the areas surveyed on the ground. Conditions are favorable for a MPB population to continue to increase towards epidemic levels.

Stillwater Creek and Soda Creek Area – MPB populations are just above endemic levels at 1.5 infested trees/acre and showed a modest increase (1.25:1) between 2002 and 2001 (Tables 1 and 2). Average BA/acre for the area was 120 and average dbh is 9.3 (Table 1). Stand characteristics are very favorable for MPB populations to continue to build above endemic levels and may progress to epidemic levels.

The MPB epidemic is expected to reduce average tree diameter and stand density. This can be seen in currently infested strip sample plots. Strip sample no. 8 shows the greatest change with average diameter dropping from 8.3 to 7.6 and average basal area per acre dropping from 118 to 86 (Table 3). Specific stand changes projected for 2003 can be also be seen in strip samples 6, 7, 9, and 18 (Table 3). Greater changes will be evident over the course of the outbreak.

Campgrounds

Campgrounds within the ANRA are almost entirely composed of mature even-aged lodgepole pine. Valuable landscape trees in the campgrounds are at high risk of MPB attack due to age (>80 years), diameter (> 8 inches), and proximity to increasing MPB infestations (Table 4). No new MPB-infested trees were seen at Willow Creek or Arapaho Bay Campgrounds, likely due to the application of preventive insecticide to these trees and prompt removal of infested trees as part of the Sulphur Ranger District's MPB management and hazard tree programs.

Table 4. Number of plots surveyed, mean basal area (BA), mean diameter at breast height (dbh), mean dwarf mistletoe rating (DMR), and mean age for Arapahoe National Recreation Area campgrounds.

Campgrounds	Number of Plots	Mean BA/acre (sq. ft)	Mean dbh (inches)	Mean DMR	Mean Age * (years)
Willow Creek*	4	65	9.7	0	89
Sunset Point*	2	40	14.5	0	72
Green Ridge	10	95	11.2	0.2	90
Arapahoe Bay--Big Rock Loop	6	165	11.8	1.6	107
Arapahoe Bay--Moraine Loop	7	86	9.8	1.7	100
Arapahoe Bay--Roaring Fork Loop	9	95	9.5	1.8	na
Stillwater	10	93	10.6	3.1	100
Cutthroat Bay	5	56	11.1	4.7	na

*Data summarized from 2001 stand exams provided by the Sulpher Ranger District.

Lodgepole pine was the only species occurring in all systematic disease survey plots, although scattered Engelmann spruce, limber pine, and aspen were present outside the plots. Lodgepole pine dwarf mistletoe was the most significant disease. Western gall rust (*Endocronartium harknessii* (J. P. Moore) Y. Hiratsuka) and camandra blister rust (*Cronartium comandrae* Peck) were present in some campgrounds; however, the incidence and severity of these two pathogens were minor. Table 4 summarizes the plot data by campground.

Although dwarf mistletoe is generally not indicative of a hazardous situation in campgrounds, large witches' brooms and dead tops create hazards if they are within striking distance of a target such as a tent pad, parking lot, or picnic table. Furthermore, large witches' brooms may act as fuel ladders.

Long-term impacts may be severe if lodgepole pine regeneration becomes heavily infected over time. As openings are created by the declining overstory, uneven-aged conditions develop that favor disease spread to young regeneration. The infected regeneration will not provide suitable replacement for the stand. Heavily infested trees can also be susceptible to secondary bark beetle attacks.

Hawksworth and Johnson (1989) found that when the average DMR within a stand is 1.0, then more than 50% of the trees are infected. Arapahoe Bay, Stillwater, and Cutthroat Bay all have average DMR's greater than 1. Any tree removal in these areas should incorporate information about mistletoe biology into silvicultural prescriptions and specifically consider the impacts of management on the incidence and severity of dwarf mistletoe.

Several of the campgrounds within the ANRA are moderately to heavily infested with dwarf mistletoe and all of the campgrounds are highly susceptible to bark beetle attacks based on average stand diameters and density. The silvicultural recommendation for reducing risk of bark beetle attacks is generally to reduce stand basal area and average diameter through tree removal and thinning. Thinning and partial harvesting can dramatically impact dwarf mistletoe infested stands by reactivating latent infections and creating conditions that favor spread from overstory to understory. The impacts of thinning on the incidence and severity of dwarf mistletoe depend on the stand dwarf mistletoe rating and whether or not future follow-up treatments are carried out. Increasing species diversity wherever possible is probably the best management strategy in campgrounds.

Recommendations

MPB Management Recommendations

The intensity of the current MPB infestation varies considerably over the susceptible stands within the ANRA's proposed MPB management areas. Analyzing areas

based on management objectives and MPB abundance will help select the best management tactics for a given area.

Where MPB populations are at endemic levels, silvicultural strategies to reduce stand susceptibility by thinning stands to below 100 sq. ft. of basal area per acre and reducing the average tree diameter to less than 8 inches may help prevent outbreak populations from building in treated stands (McGregor et. al. 1987; Amman 1989). Reducing basal area to between 60 and 80 sq. ft. per acre will increase the length of time that stands are resistant to MPB attack. Stands cut to 60 basal area per acre should remain relatively unsusceptible for about 50 years, those cut to basal area 80 for about 25 – 30 years, and those cut to 100 for about 11 to 15 years (Schmid and Amman 1992). Partial cutting lodgepole pine stands presents risk of losing additional trees to windfall and intensifying dwarf mistletoe infection present within the stands. These concerns are addressed in Appendices A and B.

Where outbreak MPB populations already exist, direct suppression through removal of infested trees as well as making stand conditions less favorable for MPB is necessary to reduce impacts. Cutting, followed by removal or treatment of beetle infested trees, should be considered a priority before beetles begin emergence in July. Logs can be hauled to sawmills where milling will kill the beetles or to “safe sites” at least one mile away from host trees susceptible to the emerging beetles (Appendix A). If infested logs are left in or near campgrounds, direct suppression of the beetles will be necessary to reduce the threat to uninfested trees in the area. Treatment strategies to kill the beetles before emergence include debarking, chipping, burning, burying, or solar treating. Detailed alternatives and considerations for managing MPB impacts are provided in Appendix A.

MPB Management Considerations for Areas Surveyed

The Arapaho Bay Road Area, a high use recreation corridor, is located very close to an intensifying MPB epidemic. Aggressive removal of infested trees will be necessary to reduce the threat. Recommended long term strategies to reduce stand susceptiblility through silvicultural treatments include a combination of sanitation, salvage and thinning.

The Green Ridge Wildland/Urban Interface Area is experiencing a rapidly building MPB population and is adjacent to a roadless area that is also seeing high levels of MPB activity. Aggressive removal of infested trees would be necessary to suppress beetle populations. Due to the high MPB populations, primarily sanitation and salvage are recommended for this area of ANRA lands. Thinning may be suitable for some stands where beetle infestation levels are low.

The Green Ridge Roadless Area is not in the designated area for active MPB management. If no action is taken here the MPB infestation is expected to increase

in suitable stands and conditions will be similar to those seen on Knight Ridge (Figure 2).

The Stillwater Creek and Soda Creek drainages have increasing endemic MPB populations. Long term strategies to reduce stand susceptibility by reducing stand density and average stand diameter may help prevent MPB populations from reaching outbreak levels in treated stands. Beetle populations are above endemic levels so removal of infested trees is recommended in addition to long term strategies of reducing stand density and average tree diameter.

Preventive spraying of high value, susceptible campground trees should be continued in the ANRA as long as MPB is active near the campgrounds. Specific formulations of carbaryl and permethrin are currently labeled for this use. Applications of carbaryl in late spring have protected lodgepole pines from attack for two years (Hastings et. al. 2001). Permethrin will provide adequate protection for one year (Leatherman and Cranshaw, 1998). Spraying is only a short term solution and does not change the stand susceptibility to future attacks. Stand density varied from a basal area of 40 sq. ft./acre to 120 sq. ft./acre in ANRA campgrounds, but average tree age and diameter indicate a high susceptibility to bark beetle attack (Table 4). Soil compaction and other campground stress factors may also make trees more susceptible to attack.

Lodgepole Pine Dwarf Mistletoe Management Recommendations

Dwarf mistletoes have many characteristics that make them excellent candidates for silvicultural control, although the methods for controlling the disease once it is established require a heavy commitment both spatially and temporally. Because they are obligate parasites they die when the tree dies and there is no need to treat or dispose of slash. They are generally host specific; therefore, encouraging non-host species is an effective management tool. Dwarf mistletoes have a long life cycle so it takes a long time to become established and spread is fairly slow, particularly in even-aged stands. The disease is more prevalent on ridges and slopes than in bottom sites. Spread of dwarf mistletoe is most effective in uneven-aged stands, particularly from overstory to adjacent regeneration. Furthermore, old infections can become latent over time and when stands are thinned or opened up these infections can reactivate. Managers can use these characteristics to develop effective silvicultural prescriptions for dwarf mistletoe management. The following management recommendations are summarized by dwarf mistletoe infection level.

Dwarf Mistletoe Control in Lightly Infested Stands: Stand DMR from 0.0 to 0.5
(Willow Creek, Green Ridge, and Sunset Point Campgrounds)

Sanitation thinning is the process of removing all infected trees during a single entry. Sanitation thinning is practical in lightly infested stands with a stand DMR less than

0.5, however, to ensure a true sanitation, all infected trees must be marked for removal. These stands should be monitored for latent infections every 3-5 years. It may be prudent to consider a prescription that protects uninfected and/or lightly infected stands from heavily infected adjacent stands. It is much easier to prevent mistletoe than to suppress it once it has infected stands. It would be a good opportunity from a mistletoe management perspective to remove the heavily infested trees that border these stands. This could be done in stages in which the most heavily infested trees (DMR 5-6) are removed in the first rotation. During a second entry within 10-15 years the residual infected trees (DMR > 3) could be removed once the regeneration has had a chance to establish itself.

Partial harvesting or small patch cuts could be an effective management strategy in stands that are very lightly infested (0-25% infection).

Dwarf Mistletoe Control in Moderately Infested Stands: Stand DMR from 0.5-3.0

(Arapahoe Bay Campground: Moraine, Big Rock, and Roaring Fork Loops)

In moderately infected stands, non-hosts should be encouraged and/or planted. Thinning is recommended in moderately infested stands with a stand DMR less than 3. This is not a true sanitation, but rather an effort to maintain the stand at a lower stand DMR to reduce losses. It is important that while removing infected trees adequate stocking levels are maintained. Additionally, opening stands up can reactivate latent dwarf mistletoe infections, so stands need to be monitored every 3-5 years with possible follow-up treatments. Regeneration should be monitored and sanitized to protect the future stand.

Residual infected trees can also be pruned to improve their overall health and vigor (Hawksworth and Johnson 1989). Pruning is effective on trees with a DMR less than or equal to 3 as long as infections are concentrated in the lower half of the crown. Prune all live branches in the 2 whorls above the last infected branch while maintaining 50% of the live crown. Trees need to be monitored for latent infections every 3-5 years.

Heavily Infested Stands: Stand DMR greater than 3.0

(Stillwater Bay and Cutthroat Bay Campgrounds)

In heavily infested stands, the most effective way to eliminate dwarf mistletoe is by clearcutting (CC). In order to effectively reduce or eliminate infection and protect regeneration, the area immediately adjacent to the replaced stand must be free of disease, or the area of the replaced stand must be large enough (greater than 20 acres) that infection from edges is insignificant (Hawksworth and Johnson 1989). Characteristics of clearcut boundaries are very important. Boundaries should be placed through natural or human-made openings such as meadows or roads. Bottom areas may also be effective. As clearcuts decrease in size below 20 acres,

the percentage of area within a half chain of the adjacent infected stand increases significantly. For example, a 1-acre clearcut has over 50 percent of its area within a half chain (33 feet) of the border, the average maximum distance dwarf mistletoe seeds will spread.

In recreation areas or other sensitive areas where clearcutting is not an option, heavily infested stands can be regenerated using several entries over a long time period. Because partial harvesting leaves an infected overstory surrounding the replaced patch, residual blocks need to be removed before the regenerating stand is either 3 feet tall or 10 years old. The intensity and distribution of mistletoe in the adjacent stand, the density of the adjacent stand, existing natural barriers, and the plans for future harvesting all will impact the success of partial or patch cutting. Regeneration needs to be monitored and sanitized to protect the future stand. In general, partial harvest systems are only recommended for heavily infested stands when a cutting cycle of 10-15 years is used, in which all of the most heavily infested trees (DMR 4-6) are removed during each cycle.

A summary of management alternatives for dwarf mistletoe infested stands is included in Appendix B.

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Action Alternatives for Mountain Pine Beetle Management

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Appendix A

Action Alternatives for Managing Mountain Pine Beetle Impacts*

Management Strategies

Several actions are available to reduce pine mortality due to attack by mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins (Order Coleoptera; Family Scolytidae). Indirect action can be taken toward the habitat and host trees required by MPB, while direct action can be taken against the MPB population itself. Currently, there is no way to suppress a large-scale MPB epidemic once it has begun. Prevention should be emphasized where MPB impacts are undesirable. The only long term strategy is to alter stand conditions to be less susceptible to mortality from MPB. Once undesirable MPB-caused mortality has begun, the intent of forest management should be to reduce adverse impacts to affected areas and minimize spread of the problem to adjacent stands. The decision to take a particular action(s) should be based on management objectives, economic factors, MPB population status and trends, stand conditions, location, resource values at risk, and other relevant issues. Consideration of MPB in the context of overall land management is important. Focusing on MPB alone may amplify other problems, such as dwarf mistletoe infestation (Hawksworth and Johnson 1989). A combination of the following action alternatives may be useful in most situations for minimizing MPB attacks.

Alternative 1: Do Nothing

Accept pine mortality and associated impacts caused by MPB as a natural phenomenon. MPB is a native insect that has been active for thousands of years. It is one of the most important biotic causes of pine mortality in conifer forests across the West (Amman et. al. 1989). MPB populations increase and decrease without direct human influence. Epidemics of MPB have many ramifications in addition to the creation of dead pine trees. These impacts vary depending upon the extent, intensity, and duration of the MPB epidemic.

Where to use - Use where other alternative actions are not desired, cannot be implemented or will not be effective. One example would be designated wilderness areas.

Advantages - No mechanical site disturbance or introduction of foreign materials into the environment will occur. Understory vegetation may prosper. From extensive and intense MPB epidemics, water yield and possibly annual stream flow will increase (McGregor and Cole 1985). Tree regeneration may be facilitated by increased sunlight reaching the forest floor. Changes in vegetation and cover may be advantageous to certain wildlife species, particularly those that

utilize dead trees. Successional trends may benefit management objectives. Public sentiment might be positively impacted by the decision to "let nature take its course." Resources could be redirected to managing uninfested stands to minimize future MPB impacts.

Disadvantages - The "do nothing" alternative means human activity will not change a stand's resistance to MPB population increase and spread. Dead trees can become safety hazards over time as they rot and fall. Timber values are reduced or lost. MPB epidemics may adversely affected visual quality by large numbers of dead and dying trees. The presence of fallen trees may affect travel within affected stands. Fire hazard will be increased during the period when dry needles are present on recently killed pines and there will be increased heavy fuel buildup after dead trees fall to the ground (Cole and Amman 1980). Regeneration may be inhibited due to loss of seed source, the covering effect of dead fallen trees, and lack of seedbed preparation. Changes in vegetation and cover may not be advantageous to certain wildlife species. Successional trends may not meet management objectives. Public sentiment may be negatively impacted, even in situations where a MPB epidemic cannot be stopped by direct action.

Alternative 2: Silvicultural Treatment

Actions that promote tree vigor and wide spacing are the primary means to reduce or prevent the impact of MPB epidemics (Amman 1989). The most recommended long-term tactic to minimize losses to MPB is to partially cut susceptible stands or harvest and subsequently replace susceptible stands. Removal of individual pines of low vigor and poor health will lessen the chance of a MPB outbreak. Lodgepole pine stands at high risk to MPB are those at lower elevation-latitudes where average tree diameter exceeds 8 inches and average tree age exceeds 80 years (Amman and others 1977). Favorable conditions for MPB in ponderosa pine stands are those where average tree diameter is greater or equal to than 8 inches and basal area is greater than or equal to 120 square feet (Schmid and Mata 1992). Partial cutting that reduces stands to 60 - 80 square feet of basal area or less and average tree diameter to below 8 inches reduces stand susceptibility to MPB. When partially cutting susceptible stands, care must be taken to avoid leaving dense pockets of mature pines, because these areas can serve as foci for MPB attack (McGregor et. al. 1987).

The risk of windfall must also be considered when partially cutting lodgepole pine stands. Soil depth and stand density contribute to windfirmness as does stand exposure. Alexander (1972) describes windfall risk based on exposure as follows:

Low Windfall Risk Situations

1. Valley bottoms except where parallel to prevailing winds and all flat areas.
2. All lower and gentle middle north and east facing slopes.
3. All lower gentle middle south and west facing slopes that are protected by considerably higher ground not far to windward.

Moderate Windfall Risk Situations

1. Valley bottoms parallel to the direction of prevailing winds.
2. All lower and gentle middle south and west facing slopes not protected to the windward direction.
3. Moderate to steep middle and all upper north and east facing slopes.
4. Moderate to steep middle south and west facing slopes protected by considerable higher ground not far to windward.

High Windfall Risk Situations

1. Ridgetops.
2. Moderate to steep middle south and west facing slopes not protected to the windward, and all upper south and west facing slopes.
3. Saddles on ridgetops.

Windfall risk is increased in the above situations by poor drainage, shallow soil and defective roots and boles

Acceptible partial cutting methods that are recommended to reduce a stand's risk to MPB include commercial thinning, shelterwood cutting, and overstory removal. Seed tree cuts can work with ponderosa pine but should not be considered for lodgepole pine stands due to the likelihood of windfall. In stands that are lightly infested with MPB, all trees that are attacked may be removed along with the most susceptible trees (generally the larger diameter lodgepole pines or mature ponderosa pine that occur in dense clumps) without exceeding standard basal area prescriptions. Heavily infested stands can be addressed with greater partial cuts in ponderosa pine but are generally not advised in lodgepole pine stands because of windthrow problems.

Clearcutting is also a useful tool to create conditions favorable to regenerating lodgepole pine and converting mature stands to younger stands. Block or patch cutting within extensive areas of pure even aged stands of lodgepole pine can reduce the potential for MPB epidemics, by reducing the area likely to be infested at one time. Also clearcutting is generally preferable to partial cutting in lodgepole stands that are understocked or heavily infested by dwarf mistletoe (Alexander 1974). Partial cutting is not recommended where the stand dwarf mistletoe rating is above 3 (Hawksworth and Johnson 1989).

Where to use – Partial cutting is a preventive treatment that addresses long-term tree and stand health. It should be incorporated into land management activity wherever MPB impacts are considered undesirable or are to be minimized. It is particularly important where timber values are the highest priority.

Advantages - Silvicultural treatment reduces the susceptibility of trees to MPB attack and has been shown to limit pine mortality from MPB in forest stands (Amman and others 1977). While this alternative does not guarantee immunity from MPB infestation, it promotes tree vigor and creates conditions known to be less favorable to MPB. Cutting green trees prior to MPB infestation maximizes economic return from timber resources, because MPB-killed trees are usually less valuable. If applied on a landscape scale, silvicultural treatments could result in a mosaic of stand susceptibility to MPB, which may reduce the development of large-scale MPB epidemics. Silvicultural treatments may allow managers to manipulate the landscape to fit management objectives better than natural processes such as MPB epidemics or stand replacing fires.

Disadvantages - This action is not suitable for areas where tree cutting is undesirable, unaffordable or not allowed. Examples of such areas are wilderness, steep slopes, and where the visual quality of cut areas would be less than that of dead trees. It is not possible in areas with no logging industry.

Alternative 3: Sanitation and Salvage Harvesting

Sanitation harvesting is a treatment applied to currently infested pine stands. Green trees with immature MPB developing under the bark are cut and removed to an area at least one mile from susceptible pines or processed at a mill prior to MPB emergence. Sanitation must be completed prior to July when MPB emerges to be effective. Salvage harvesting is cutting pines already killed by MPB after beetle emergence. Salvage does not reduce MPB populations but is commonly done in conjunction with sanitation.

Where to use - Stands that are currently under attack where reduction of the MPB population and recovery of timber resource values is desirable and where timber harvesting activity is acceptable. Especially appropriate are infested stands in proximity to uninfested, susceptible high value stands where mortality from MPB would threaten land management objectives. Sanitation could also be used concurrently with silvicultural treatment in stands where the MPB population has not yet reached epidemic levels.

Advantages - MPB populations can be significantly reduced by removing most or all infested trees prior to the emergence of the next generation of beetles. Sanitation provides a degree of protection to surrounding, uninfested trees and stands by removing a nearby source of attacking beetles. Timber volume could be recovered that would otherwise be lost. Initial increased fire potential from

dead trees holding dry needles is reduced and future fire danger from heavy fuels created by dead and down trees is also reduced. The visual impact of dead and dying trees is reduced. The hazard from falling trees is lowered. Pine regeneration will be encouraged by both the site disturbance and the reduction in shade.

Disadvantages - There is little time for implementation of sanitation because infested trees must be removed before MPB emergence. Sanitation/salvage harvesting has not been demonstrated to suppress MPB populations on a scale larger than the individual stand, although this may occur in some cases. It should not be considered an efficacious control tactic across large landscapes or during severe MPB epidemics where MPB immigration into treated stands is likely. Sanitation/salvage harvesting undertaken without additional considerations for stand health and survival can lead to residual conditions that have other significant problems, such as increased spread and intensification of dwarf mistletoe (McGregor and Cole 1985). Tree removal may not be aesthetically acceptable in some areas. Adverse site and soil disturbance may occur.

Alternative 4: Infested Tree Treatment

Cut and individually treat infested pines prior to the maturation and emergence of MPB brood. Any action that kills most or all of the MPB within infested trees prior to MPB emergence falls under this direct control action alternative. **The following examples do not work in all situations and are not all supported by rigorous research results.** Examples of infested tree treatment techniques are as follows: (1) Cut and burn on site; (2) Cut and bury at least 6 inches deep on site; (3) Cut and chip; (4) Cut and remove the bark from infested portions of logs before the immature MPB transform to adult beetles; (5) Cut and expose to direct sunlight such that the trunk surface receives sufficient heat to kill the beetles under the bark, rotating the trunk to ensure complete exposure (Negron et. al. 2001); (6) Cut and cover with thick clear plastic such that the trunk surface receives sufficient heat to kill the beetles under the bark (Negron et. al. 2001); It is important to check any treatment near the end of June before adult beetle emergence. Infested tree treatments differs from sanitation harvesting (Alternative 3) because it is usually applied on a smaller scale and is often not conducted in conjunction with salvage harvesting.

Where to use - This alternative is most appropriate for treating small spots in areas of great concern, such as those adjacent to residences and within developed recreation sites. It may also be appropriate in unroaded areas, on slopes too steep to harvest with conventional methods, in areas where the disturbance from conventional harvest activity is unacceptable, and in areas where there is no possibility of sanitation/salvage harvesting due to insufficient volume, no bids or other reasons.

Advantages - Much of the immature MPB population can be eliminated from the treated area. As a result of infested tree treatment, risk to surrounding uninfested trees is reduced by removing a nearby source of attacking beetles. This alternative may also provide time for silvicultural treatment to be implemented. The fire hazard from the presence of dead pines retaining dry needles is lowered. The visual impact of dead and dying trees is reduced. The subsequent hazard from falling trees is lowered. Pine regeneration may be encouraged by the reduction of shade. Firewood may be recovered from this treatment.

Disadvantages - There is little time for implementation, because the developing MPB brood must be destroyed before the next emergence period in July. Localized beetle populations can be suppressed by this action, but it rarely reduces a stand's susceptibility to MPB attack. Additional follow-up treatments may be needed in subsequent years because it can be difficult to locate and treat all infested trees in an area. Infested trees may be inadvertently moved as firewood prior to MPB emergence, possibly spreading the infestation.

Alternative 5: Protection of High Value Trees

Prior to the attack period of MPB, boles of green, uninfested, high value trees may be sprayed with a labeled insecticide that kills attacking MPB to prevent infestation.

Where to use - This action is appropriate for high value individual trees such as found in developed recreation sites when there is a threat from active MPB populations in the vicinity. Because specialized equipment may be required, trees must be relatively accessible. This action is not effective for trees that are already infested by MPB.

Advantages - Controlled experiments and operational experiences have established this action as very effective in protecting individual pines from infestation. Specific formulations of carbaryl and permethrin are currently labeled for this use. Protection using carbaryl has been demonstrated to last from 10 - 18 months, meaning that a late spring application may afford two years of protection (Hastings and others 2001).

Disadvantages - Carbaryl and permethrin are toxic to insects other than MPB. Insecticide applied as protection does not effectively reduce the beetle population or address stand susceptibility to future MPB outbreaks. It does not guarantee absolute protection, especially if the application is not thorough and complete. Insecticide treatment can be very expensive, especially if large areas require treatment. Potential environmental hazards exist from improper use, storage or disposal of chemicals and chemically treated wood. There may be a shortage of qualified pesticide applicators. Many citizens have concerns about environmental contamination and safety.

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* Revision of *Action Alternatives For Managing Mountain Pine Beetle Impacts* by W. C. Schaupp, Jr.

Appendix B

Management Alternatives for Stands Infested with Dwarf Mistletoe

Alternative 1: Do Nothing

Under this alternative dwarf mistletoe will continue to cause slow, progressive decline and mortality of host species within the stand. Additionally, long-term impacts may be severe as lodgepole pine regeneration becomes more heavily infected. As openings are created by the declining overstory, uneven-aged conditions develop that favor disease spread to young regeneration. The infected regeneration will not provide suitable replacement for the future stand.

Alternative 2: Implement Dwarf Mistletoe Control

Silvicultural strategies for dwarf mistletoe infested stands have been outlined by several researchers and are summarized below (Hawksworth and Johnson 1989, and Geils et. al. 2002).

1) **Plant or Favor Non-Host Species:** Plant non-host species in the understory of infested stands to eventually replace the stand when the overstory is removed or falls apart. Plant species adapted to the site and moisture conditions of the area. In lodgepole pine areas some species to plant and/or favor include engelmann spruce, Douglas-fir, subalpine fir, aspen, bristlecone pine, and limber pine.

2) **Prune Witches' Brooms and Infected Branches:** Pruning is done to reduce dwarf mistletoe spread and improve tree vigor. Pruning is only recommended in high value areas because it is both labor intensive and expensive. Pruning is effective on trees with a DMR less than or equal to 3 as long as infections are concentrated in the lower half of the crown. Prune all live branches in the 2 whorls above the last infected branch while maintaining 50% of the live crown. Trees need to be monitored for latent infections every 3-5 years.

3) **Chemical Controls:** Ethephon is a naturally occurring plant growth regulator that has been used as a chemical control for dwarf mistletoe infested stands. When sprayed on infected trees in the fall, ethephon causes dwarf mistletoe shoots to drop off host trees before seeds are dispersed. This type of treatment may be beneficial in areas where planting non-host species in the understory is not an option. Ethephon does not kill the entire mistletoe plant but it provides short-term protection (1-3 years). Reapplication is necessary until the infected overstory can be removed. Generally, pruning is more economical and effective than ethephon spraying.

4) **Remove Infected Trees:**

   a) **Create Buffer Strips:** Remove all infected trees within 33-50 feet of an area that needs to be protected such as an uninfected stand or an area that has just been treated. Thirty-three feet is the average maximum distance that dwarf mistletoe seeds will spread.

   b) **Sanitation Thin:** Sanitation thinning is the removal of all infected overstory and understory trees. A strict sanitation can only be done in lightly infested stands (Stand DMR less than 0.5 = 40 % infection) otherwise the removal of too many trees would leave stands understocked. Generally, thinning is recommended in stands with a DMR less than 3. This is not a true santitation, but rather an effort to maintain the stand at a lower stand DMR to reduce losses. Opening stands up can reactivate latent dwarf mistletoe infections, so stands need to be monitored every 3-5 years with possible follow-up management.

   c) **Even-Aged Management (Harvest and Regenerate the Stand):** Even-aged management, either through clearcutting or shelterwood harvests, is the most effective way to eliminate dwarf mistletoe from heavily infested stands. In order to successfully reduce or eliminate infection and protect regeneration, the area immediately adjacent to the replaced stand must be free of disease, or the area of the replaced stand must be large enough (greater than 20 acres) that infection from edges is insignificant. Boundaries should be placed through natural or manmade openings such as meadows or roads.

   d) **Uneven-aged Management (Partial Cutting):** Uneven-aged management is generally not recommended in heavily infested stands because the small units and presence of scattered infected overstory trees leaves stands very susceptible to rapid reinvasion from the overstory to the new regeneration. As a general guideline, small group selection or patch clearcuts should only be used in areas where only 15-25% of trees are infected. To avoid the problems associated with partial harvest systems in heavily infested stands, a cutting cycle of 10-15 years must be used, in which all of the most heavily infested trees (DMR 4-6) are removed during each cycle.

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[illegible]

[illegible]

d) **Uneven-aged Management (Partial Cutting):** [illegible]

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